

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/00519

## A. CLASSIFICATION OF SUBJECT MATTER:

IPC (6):

A61K 31/12, 31/135, 31/15, 31/165, 31/44, 31/505; C07D 213/89, 239/52; C07C 233/00, 257/00, 241/00, 249/00, 49/105, 49/163, 49/76, 49/786, 49/82

## A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

514/269, 274, 352, 353, 354, 357, 617, 638, 639, 640, 678, 688; 544/312, 314; 546/304, 306, 309, 314, 329; 564/161, 248, 251, 255, 265; 568/325, 331

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/00519

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	Chemical Abstract, Volume 103, Number 37354, issued 1985, Nagarajan et al, "Antiimplantation agent : part II - 1,2-diaryl - 1,2,3,4-tetrahydroisoquinolines", Indian J. Chem., Sect. B (1985), 24B(1), pages 83-97, see entire abstract.	1-7, 12-14 and 20 ----- 1-7, 12-14 and 20

Form PCT/ISA/210 (continuation of second sheet)(July 1992)\*

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/00519

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : Please See Extra Sheet.

US CL : Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 514/269, 274, 352, 353, 354, 357, 617, 638, 639, 640, 678, 688; 544/312, 314; 546/304, 306, 309, 314, 329; 564/161, 248, 251, 255, 265; 568/325, 331

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CAS ONLINE

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ----- Y	Chemical Abstract, Volume 116, Number 255335, issued 1992, Bender et al, "Preparation of phenylalkyloxamide as cyclic nucleotide phosphodiesterase and tumor necrosis factor inhibitors", WO, A, 92/00968, 23 January 1992, see entire abstract.	1-7, 12-14 and 20 ----- 1-7, 12-14 and 20
X ----- Y	Chemical Abstract, Volume 92, Number 6207, issued 1980, Pirisino et al, "Anilides with potential antibacterial effect", Studi Sassar., Sez. 2 (1977), 55(3-4), pages 307-313, see entire abstract.	1-7, 12-14 and 20 ----- 1-7, 12-14 and 20

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*E* earlier document published on or after the international filing date	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z*	document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means		
*P* document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

24 APRIL 1996

Date of mailing of the international search report

06 MAY 1996

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23. The method of claim 20, wherein said compound is selected from the group consisting of:

N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-allyloxy-5-chloroaniline;

N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-hydroxy-3-allyl-5-chloroaniline;

1-(3-Cyclopentyloxy-4-methoxyphenyl)phenone-O-(aminocarbonyl) oxime;

1-(3-cyclopentyloxy-4-methoxyphenyl)-(2-(5-(pyrimid-2,4-dionyl)))ethanone;

N-Benzyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(methylnaphth-1-yl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(4-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(2-trifluoromethylbenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(4-fluorophenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(2-fluorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine; and

N-(2-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine.

24. A method of effecting PDE V inhibition to a patient requiring the same, comprising administering an effective amount of the compound of claim 1.

1-(3-Cyclopentyloxy-4-methoxyphenyl)phenone-O-(aminocarbonyl)oxime;  
1-(3-cyclopentyloxy-4-methoxyphenyl)-(2-(5-(pyrimid-2,4-dionyl)))ethanone;  
N-Benzyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;  
N-(methylnaphth-1-yl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;  
N-(4-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;  
N-(2-trifluoromethylbenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;  
N-(4-fluorophenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;  
N-(2-fluorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine; and  
N-(2-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine.

22. A method of treating a mammal suffering from a disease state selected from the group consisting of asthma, allergies, inflammation, depression, dementia, atopic diseases, rhinitis and disease states associated with abnormally high physiological levels of cytokine, comprising administering an effective amount of the compound of claim 1.

N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-allyloxy-5-chloroaniline;

N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-hydroxy-3-allyl-5-chloroaniline;

1-(3-Cyclopentyloxy-4-methoxyphenyl)phenone-O-(aminocarbonyl)oxime;

1-(3-cyclopentyloxy-4-methoxyphenyl)-(2-(5-(pyrimid-2,4-dionyl)))ethanone;

N-Benzyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(methylnaphth-1-yl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(4-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(2-trifluoromethylbenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(4-fluorophenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(2-fluorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine; and

N-(2-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine.

20. A pharmaceutical composition comprising the compound of claim 1.

21. The pharmaceutical composition of claim 20, wherein said compound is selected from the group consisting of:

N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-allyloxy-5-chloroaniline;

N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-hydroxy-3-allyl-5-chloroaniline;

17. The compound of claim 1, selected from the group consisting of:

N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-allyloxy-5-chloroaniline;

N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-hydroxy-3-allyl-5-chloroaniline;

1-(3-Cyclopentyloxy-4-methoxyphenyl)phenone-O-(aminocarbonyl)oxime;

1-(3-cyclopentyloxy-4-methoxyphenyl)-(2-(5-(pyrimid-2,4-dionyl)))ethanone;

N-Benzyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(methylnaphth-1-yl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(4-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(2-trifluoromethylbenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(4-fluorophenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

N-(2-fluorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine; and

N-(2-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine.

18. A method of effecting selective PDE IV inhibition to a patient requiring the same, comprising administering an effective amount of the compound of claim 1.

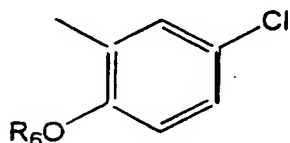
19 The method of claim 18, wherein said compound is selected from the group consisting of:

11. The compound of claim 2, wherein Z is  $-\text{C}(\text{Cl})=\text{N}-$ .

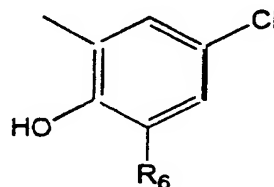
12. The compound of claim 2, wherein  $\text{X}_1$  and  $\text{X}_2$  are O.

13. The compound of claim 2 wherein  $\text{R}_4$  is an unsubstituted or substituted phenyl or benzyl.

14. The compound of claim 6 wherein  $\text{R}_4$  is a substituted phenyl having one of the following structures:

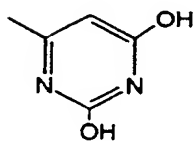


or

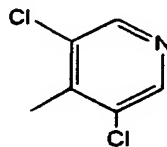


wherein  $\text{R}_6$  is an unsubstituted or substituted lower alkyl.

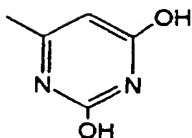
15. The compound of claim 7 wherein  $\text{R}_4$  is one of:



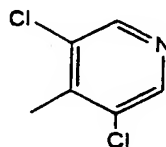
or



16. The compound of claim 9 wherein  $\text{R}_4$  is one of:

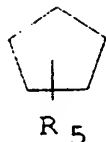


or





5. The compound of claim 1 wherein  $R_2$  is methyl or ethyl and wherein  $R_1$  is cyclopentyl optionally substituted by  $R_5$  as shown in the following structural formula:



wherein  $R_5$  is hydrogen or a saturated or unsaturated straight-chain lower alkyl group containing from about 1 to about 6 carbon atoms, unsubstituted or substituted with one or more halogen atoms, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, alkoxy groups, alkoxycarbonyl, carboxamido or substituted or unsubstituted amino groups.

6. The compound of claim 2 wherein Z is a linkage selected from the group consisting of  $-\text{CH}_2\text{CONH}-$ ,  $-\text{CH}_2\text{NHCO}-$ .

7. The compound of claim 2, wherein Z is  $-\text{CH}_2\text{CO}-$  or  $-\text{COCH}_2-$ .

8. The compound of claim 2, wherein Z is  $-\text{C}(=\text{NOCONHQ})-$ .

9. The compound of claim 2, wherein Z is  $-\text{C}(=\text{NQ})\text{NH}-$ .

10. The compound of claim 2, wherein Z is  $-\text{C}(=\text{NQ})\text{NHNH}$ .

groups preferably containing from about 6 to about 10 carbon atoms, or heterocyclic groups containing nitrogen, oxygen or sulfur in the ring; said alkyl, cycloalkyl, cycloalkyl-alkyl, aryl, and aryl-alkyl groups being unsubstituted or substituted by halogen atoms, hydroxyl groups, cyano groups, carboxyl groups, alkoxy groups, alkoxycarbonyl, carboxamido or substituted or unsubstituted amino groups, or one or more lower alkyl groups having from 1 to 3 carbon atoms;

Q is R<sub>4</sub>, H or lower alkyl;

with the exceptions that:

when Z=-C(=NOCONHQ)-, R<sub>4</sub> is not benzyl;

when Q is H, Z is not -C(OQ)=N-; and

R<sub>1</sub> and R<sub>2</sub> are both not hydrogen.

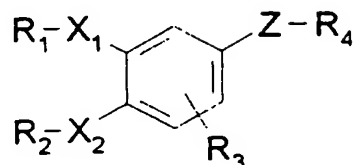
2. The compound of claim 1, wherein R<sub>1</sub> is a C<sub>1-12</sub> alkyl or cycloalkyl of 3-6 carbon atoms, said cycloalkyl may be substituted by one or more alkyl groups or by one or more halogens, R<sub>2</sub> is hydrogen, or C<sub>1-12</sub> alkyl, and wherein R<sub>3</sub> is hydrogen, lower alkyl or halogen.

3. The compound of claim 2 wherein R<sub>2</sub> is lower alkyl.

4. The compound of claim 3 wherein R<sub>2</sub> is cycloalkyl optionally substituted by one or more halogens.

WHAT IS CLAIMED IS:

1. A compound of the formula:



wherein:

$X_1$  and  $X_2$  may be the same or different and each is O or S;

$R_2$  and  $R_3$  may be the same or different and each is selected from the group consisting of hydrogen, saturated or unsaturated straight-chain or branched  $C_{1-12}$  alkyl groups, cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 10 carbon atoms in the cycloalkyl moiety;

$R_4$  is hydrogen, halogen, or a saturated or unsaturated straight-chain or branched  $C_{1-12}$  alkyl group, a cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 7 carbon atoms in the cycloalkyl moiety;

Z is a linkage selected from  $-NHCH_2-$ ,  $-CH_2NH-$ ,  $-CH_2CONH-$ ,  $-CH_2NHCO-$ ,  $-CH_2CO-$ ,  $-COCH_2-$ ,  $-CH_2COCH_2-$ ,  $-C(=NQ)NH-$ ,  $-C(=NOCONHQ)-$ ,  $-C(Cl)=N-$ ,  $-C(OQ)=N-$ ,  $-C(=NQ)NHNH$  and  $-C(NHNHQ)=N-$ ;

$R_4$  is a phenyl or benzyl or a 6-membered heteroaryl group which may be unsubstituted or substituted with one or more halogen atoms, alkyl groups, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, alkoxy groups, alkoxycarbonyl, amido, carboxamido, substituted or unsubstituted amino groups, cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 10 carbon atoms in the cycloalkyl moiety, aryl or aralkyl

While the invention has been illustrated with respect to the production and use of a particular compound, it is apparent that variations and modifications of the invention can be made without departing from the spirit or scope of the invention.

Compound	<u>PDE III</u>	<u>PDE IV</u>	<u>PDE V</u>
27	>300	15.6	>300
28	>300	0.21	>300
29	>300	34.6	>300
30	100	0.6	>100
31	>300	75	>300
32	100	17.8	91.2
33	125	16.9	56.9
34	119.4	4.2	>300
35	>300	26.5	>300
36	6.4	0.37	4.6
37	>300	4.66	>100
38	147	38.7	>300
39	>300	0.594	>300
40	>300	0.004	>100
41	184	0.77	27.8
42	>300	5.56	>100
43	60.43	0.385	34.81
44	57.96	0.362	25.65
45	-	-	-
46	-	-	-
rolipram	620	2.8	500

Thus, it can be seen from the foregoing that compounds prepared in accordance with the present invention have high levels of PDE IV inhibition while, at the same time relatively low levels of PDE III inhibition. It can also be seen that some of the compounds are also effective PDE V inhibitors.

TABLE 5  
IC<sub>50</sub>( $\mu$ M)

Compound	PDE III	PDE IV	PDE V
1	> 1000	2.2	71.9
2	> 1000	2.8	37
3	89.5	1.8	38
4	205.4	3.2	>300
5	> 300	0.3	2.83
6	110	1.47	>100
7	18.5	3.67	>100
8	>300	0.5	6.88
9	>300	0.005	84.8
10	58.2	0.26	>100
11	>300	>100	83.2
12	>300	65.8	>300
13	36.3	0.18	>300
14	>300	51.8	>300
15	>300	0.52	9
16	100	0.22	7.9
17	>300	2.5	>300
18	>300	11.8	>300
19	37.5	11.6	3.9
20	278	16.1	>300
21	>300	32.8	>300
22	>300	38.7	12
23	>300	19	>300
24	>300	49.6	>300
25	>300	242	31.6
26	>300	203	44.3

-20°C. PDE V can typically be retained for up to four weeks with little or no loss of activity.

5        Measuring Type V PDE Activity: Enzyme activity are  
assessed by measuring the hydrolysis of [<sup>3</sup>H]-cyclic GMP,  
as described by Thompson et al. (Thompson, W.J., Teraski,  
W.L., Epstein, P.N., Strada, S.J.: Adv. Cyclic Nucleotide  
Res. 10:69, 1979). The cyclic GMP concentration used in  
10       this assay is 0.2 µM, which approximates to the K<sub>m</sub> value.  
Protein concentration is adjusted to ensure that no more  
than 15% of the available substrate is hydrolyzed during  
the incubation period.

15       All test compounds are dissolved in dimethyl  
sulfoxide (final concentration of 2.5%). This  
concentration of dimethyl sulfoxide inhibits enzyme  
activity by approximately 10%. The reference Type V PDE  
inhibitor zaprinast is evaluated with each assay.

20       The compounds are tested over concentration range:  
0.1, 1, 10, 100 µM (n=1), and IC<sub>50</sub> determinations are made  
using 5 appropriate concentrations (n=2).

#### EXAMPLE 48

25       Following the above procedures, the PDE III, PDE IV  
and PDE V inhibition for the compounds of Examples 1-46,  
and rolipram were tested and compared. The results are  
shown in the Table 5 below:

of the available substrate is hydrolyzed during the incubation period.

All test compounds are dissolved in dimethyl sulfoxide (final concentration of 2.5%). This concentration of dimethyl sulfoxide inhibits enzyme activity by approximately 10%.

Type V Phosphodiesterase Enzyme Isolation Protocol  
Enzyme Isolation Procedure:

The Type V PDE is isolated using a procedure similar to that previously described by Weishaar et al., Hypertension 15:528, (1990). Briefly, 1-2 units of platelets are suspended in an equal volume of buffer A (20 mM Tris-HCl, pH 7.5, containing 2 mM magnesium acetate, 1 mM dithiothreitol, and 5 mM Na<sub>2</sub>EDTA) using a polytron. The proteinase inhibitor phenylmethylsulfonyl fluoride (PMSF) are also included in this buffer at a final concentration of 200 µM. This and all subsequent procedures are performed at 0-4°C. The homogenate is then centrifuges at 100,000 xg for 60 minutes. The supernatant is then removed and filtered through four layers of gauze and applied to a DEAE-Trisacryl M column. The column is washed with several bed volumes of buffer B (20 mM Tris-HCl, pH 7.5, containing 2 mM magnesium acetate, 1 mM diothiothreitol, and 200 µM PMSF) and eluted by two successive linear NaCl gradients (0.05-0.15 M, 300 ml total; 0.15-0.40 M, 200 ml total). Five ml fractions are collected and assayed for cyclic AMP and cyclic GMP PDE activity. Fractions that contain PDE V are pooled and dialyzed overnight against 4 L of buffer C (20 mM Tris-HCl, pH 7.5, containing 2 mM magnesium acetate and proteinase inhibitors). The dialyzed PDE V is then concentrated to 10% of the original volume, diluted to 50% with ethylene glycol monoethyl ether and stored at



concentration of dimethyl sulfoxide inhibits enzyme activity by approximately 10%.

#### Type IV Phosphodiesterase Enzyme Isolation Protocol

5 The Type IV PDE is isolated from bovine tracheal smooth muscle using a procedure similar to that previously described by Silver, P.J., et al. Eur. J. Pharmacol. 150:85,1988. Briefly, smooth muscle from  
10 bovine trachea is minced and homogenized using a polytron in 10 volumes of an extraction buffer containing 10 mM Tris-acetate (pH 7.5), 2 mM magnesium chloride, 1 mM dithiothreitol and 2,000 units/milliliters of aprotinin. This and all subsequent procedures are performed at 0-4°C.  
15 The homogenate is sonicated and then centrifuged at 48,000 x g for 30 minutes. The resulting supernatant is applied to a DEAE Trisacryl M column previously equilibrated with sodium acetate and dithiothreitol. After applications of the sample, the column is washed  
20 with sodium acetate/dithiothreitol, after which the different forms of PDE are eluted from the column using a linear Tris-HCl/NaCl gradient. Fractions containing Type IV PDE are collected, dialyzed and concentrated to 14% of the original volume. The concentrated fractions  
25 are diluted to 50% with ethylene glycol and stored at -20°C.

#### Measuring Type IV PDE Activity

30 Enzyme activity is assessed by measuring the hydrolysis of [<sup>3</sup>H]-cyclic AMP, as described by Thompson, W.J., et al., Adv. Cyclic Nucleotide Res. 10:69, 1979. The cyclic AMP concentration used in this assay is 0.2 μM, which approximates the K<sub>m</sub> value. Protein concentration is adjusted to ensure that no more than 15%

5       genate centrifuged at 100,000 x g for 60 minutes. This  
and all subsequent procedures are performed at 0-4°C. The  
supernatant is then filtered through four layers of gauze  
and applied to a DEAE-Trisacryl M column, previously  
10       equilibrated with buffer B (20 mM Tris-HCl, pH 7.5,  
containing 1 mM magnesium acetate, 1 mM dithiothreitol  
and 200 µM PMSF). After application of the sample, the  
column is washed with several bed volumes of buffer B,  
after which the different forms of PDE are eluted from  
15       the column using two successive linear NaCl gradients  
(0.05-0.15 M, 300 milliliters total; 0.15-0.40 M, 200  
milliliters total). Five milliliter fractions are  
collected and assayed for cyclic AMP and cyclic GMP PDE  
activity. Fractions containing PDE III activity are  
20       pooled and dialyzed overnight against 4 liters of buffer  
B. The dialyzed PDE III is then concentrated to 10% of  
the original volume, diluted to 50% with ethylene glycol  
monoethyl ether and stored at -20°C. PDE III can  
typically be retained for up to four weeks with little or  
no loss of activity.

#### Measuring Type III PDE Activity

25       Enzyme activity is assessed by measuring the  
hydrolysis of [<sup>3</sup>H]-cyclic AMP, as described by Thompson,  
W.J., et al., Adv. Cyclic Nucleotide Res. 10:69, 1979.  
The cyclic AMP concentration used in this assay is 0.2  
µM, which approximates to the K<sub>m</sub> value. Protein  
concentration is adjusted to ensure that no more than 15%  
of the available substrate is hydrolyzed during the  
30       incubation period.

All test compounds are dissolved in dimethyl  
sulfoxide (final concentration of 2.5%). This

was left to stir at room temperature for half an hour, then sodium cyanoborohydride (0.09 g, 1.45 mmole) was added. The pH of the reaction mixture was adjusted to ~6 and the solution left to stir for 2 hours. The reaction mixture was quenched with NaOH (1N, 50 ml), methanol was removed *in vacuo* and the resulting mixture extracted with ethyl acetate (2 x 50 ml). The organic extracts were combined and washed with water (50 ml), dried (MgSO<sub>4</sub>) and concentrated *in vacuo* to yield a yellow foam (0.59 g). Flash chromatography (SiO<sub>2</sub>; ethyl acetate : pentane [2 : 3]) isolated two geometrical isomers: isomer 1: colorless oil (0.18 g), recrystallized from ethyl acetate / pentane to yield a colorless solid (0.13 g), m.p. 161-2°C; isomer 2: colorless oil (0.26 g), recrystallized from ethyl acetate / pentane to yield a colorless solid (0.20 g), m.p. 156-7°C.

#### EXAMPLE 47

Protocols for PDE III, PDE IV and PDE V inhibition activity are set forth below:

##### Type III Phosphodiesterase

##### Enzyme Isolation Protocol

The Type III PDE is isolated from human platelets using a procedure similar to that previously described by Weishaar, R.E., et al., Biochem. Pharmacol., 35:787, 1986. Briefly, 1-2 units of platelets are suspended in an equal volume of buffer (20 mM Tris-HCl, pH 7.5, containing 2 mM magnesium acetate, 1 mM dithiothreitol, and 5 mM Na<sub>2</sub> EDTA). The proteinase inhibitor phenylmethyl-sulfonyl fluoride (PMSF) is also included in this buffer at a final concentration of 200 µM. The suspension is homogenized using a polytron and the homo-

TABLE 4

EX.	NAME	REACTION TIME (hr)	M.P. ° C	PHYSICAL PROPERTIES
43	Methyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzimidate	4	83-84	colorless crystalline solid
44	Ethyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzimidate	4	73	colorless crystalline solid

EXAMPLE 45

N-amino-N -(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine

To N-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzimidino chloride (4.72 g, 11.80 mmole) in chloroform (50 ml) was added hydrazine monohydrate (9.2 ml, 16 equivalents). The solution was heated at reflux for 1 hour. The aqueous fraction was removed. The organic layer was dried (MgSO<sub>4</sub>) and concentrated *in vacuo* to yield a pale yellow oil. The desired product was isolated by flash chromatography (SiO<sub>2</sub>; ethyl acetate : pentane [1 : 4]) in quantitative yield. Recrystallization from ethyl acetate / pentane yielded two geometrical isomers: isomer 1: colorless crystalline solid (0.29 g), m.p. 130-1°C, resolidifies immediately and remelts at 187-8 °C; isomer 2: colorless crystalline solid (2.82 g), m.p. 187°C. Isomer 1 converts to isomer 2 in the presence of acid.

EXAMPLE 46

N-isopropylamino-N -(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidines

To N-amino-N -(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine ([Isomer 1] 0.50 g, 1.26 mmole) was added acetone (0.44 g, 7.59 mmole) followed by 1N HCl and methanol (1.2 ml). The mixture

crystalline solid. The time of the reaction and the properties of the product are given in Table 3.

TABLE 3

EX.	NAME	REACTION TIME (hr)	M.P. ° C	PHYSICAL PROPERTIES
41	N'-(3,5-dichloropyrid-4-yl)- 3-cyclopentyloxy-4-methoxy benzamidine	6	170	colorless crystalline solid
42	N-methyl-N'-(3,5-dichloro pyrid-4-yl)-3-cyclopentyloxy -4-methoxybenzamidine	4	184- 185	colorless crystalline solid

EXAMPLES 43 - 44Alkyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzimidates

To N-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzimidino chloride (200 milligrams, 0.5 mmol) in methylene chloride (2 milliliters) was added the alcohol (4 milliliters). In both cases, the reaction mixture was heated to 45°C in a sealed vessel for a sufficient time, allowed to cool, and concentrated *in vacuo* to afford a yellow solid. The desired product was isolated by flash chromatography (SiO<sub>2</sub>; ethyl acetate : pentane [1 : 4]) then recrystallized from ethyl acetate / pentane to yield the product, as a colorless crystalline solid. The time of the reaction and the properties of the product are given in Table 4.

34	N-(2-carbomethoxyphenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	48	144-145	pale yellow needles
35	N-(4-acetamidophenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	48	145-146	pale yellow prisms
36	N-(2-carboxyphenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	48	225-226	off-white crystals
37	N-benzyl-N-methyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	4.5	52-55	colorless solid (foam)
38	N-(2-amidophenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	48	143	colorless solid
39	N-(4-carbomethoxyphenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	24	191-192	very pale yellow solid
40	N-(methylnaphth-1-yl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	24	144-147	pale yellow solid

**EXAMPLES 41 - 42****N-Alkyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidines**

To N-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzimidino chloride (1.05 grams, 2.6 mmol) in methylene chloride (10 milliliters) was added a 2.0 M solution of the methylamine or ammonia in MeOH (20 milliliters, 40 mmol). In each case, the reaction mixture was heated to 45°C in a sealed vessel for a sufficient time, allowed to cool, and concentrated *in vacuo* to afford an off-white solid. The desired product was isolated by flash chromatography (SiO<sub>2</sub>; ethyl acetate : pentane [2 : 3]) then recrystallized from ethyl acetate / pentane to yield the product, as a colorless

22	N-(3-fluorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	24	149	colorless crystalline solid
23	N-(2-methylbenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	30	185-186	colorless crystalline solid
24	N-(4-trifluoromethylphenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	43	184-185	colorless crystalline solid
25	N-(3-trifluoromethylphenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	43	192-193	colorless crystalline solid
26	N-(3-fluorophenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	43	199	colorless crystalline solid
27	N-(2-fluorophenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	43	116-117	colorless crystalline solid
28	N-(4-fluorophenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	43	215-216	colorless crystalline solid
29	N-(3-methylbenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	29.5	117-118	colorless crystalline solid
30	N-(2-trifluoromethylphenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	48	171	colorless crystalline solid
31	N-(4-hydroxyphenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	23 + 48 hrs at r.t.	283-284	colorless crystalline solid
32	N-(3-carboxyphenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	48	267-268	colorless crystalline solid
33	N-(4-carboxyphenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxy benzamidine	48	167-168	colorless crystalline solid

TABLE 2

EX.	NAME	REACTION TIME (hr)	M.P. ° C	PHYSICAL PROPERTIES
12	N-(3-trifluoromethylbenzyl)- N'-(3,5-dichloropyrid-4-yl)- 3-cyclopentyloxy-4- methoxybenzamide	28	107- 108	colorless crystalline solid
13	N-(2-trifluoromethylbenzyl)- N'-(3,5-dichloropyrid-4-yl)-3- -cyclopentyloxy-4-methoxy benzamide	28 + 20 hrs r.t	135	colorless crystalline solid
14	N-(4-trifluoromethylbenzyl)- N'-(3,5-dichloropyrid-4-yl)- 3-cyclopentyloxy-4-methoxy benzamide	20	164- 165	colorless crystalline solid
15	N-(4-fluorobenzyl)-N'-(3,5-di chloropyrid-4-yl)-3-cyclo pentyloxy-4-methoxy benzamide	24	147	colorless crystalline solid
16	N-(2-fluorobenzyl)-N'-(3,5-di chloropyrid-4-yl)-3-cyclo pentyloxy-4-methoxy benzamide	16	148	colorless crystalline solid
17	N-(3-chlorobenzyl)-N'-(3,5-di chloropyrid-4-yl)-3-cyclo pentyloxy-4-methoxy benzamide	20	134- 135	colorless crystalline solid
18	N-(4-methylbenzyl)-N'-(3,5-di chloropyrid-4-yl)-3-cyclo pentyloxy-4-methoxy benzamide	24	170	colorless crystalline solid
19	N-(2-methoxybenzyl)-N'-(3,5- dichloropyrid-4-yl)-3-cyclo pentyloxy-4-methoxy benzamide	24	136- 137	colorless crystalline solid
20	N-(2-chlorophenyl)-N'-(3,5-di chloropyrid-4-yl)-3-cyclo pentyloxy-4-methoxy benzamide	24	143- 144	colorless crystalline solid
21	N-(2,6-dimethylphenyl)-N'-( 3,5-dichloropyrid-4-yl)-3- cyclopentyloxy-4-methoxy benzamide	29	184- 185	colorless crystalline solid



chloride as a white solid. The product had a melting point of 120°.

EXAMPLES 12 - 40

5        N-Aryl- or N-Benzyl-N'-(3,5-dichloropyrid-4-yl)-3-  
         cyclopentyloxy-4-methoxybenzamidines

10        To N-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzimidino chloride (1.57 grams, 3.95 mmol) in xylenes (35 milliliters) was added the benzylamine or aniline derivative (2.4 equivalents). In each case, the reaction mixture was heated to reflux for a sufficient period of time, allowed to cool, washed with 1N HCl (2 x 50 milliliters), dried (MgSO<sub>4</sub>) and concentrated *in vacuo* to afford a brown solid. The desired product was isolated by flash chromatography (SiO<sub>2</sub>; ethyl acetate : pentane [1 : 5]) then recrystallized from ethyl acetate / pentane to yield the crystalline product.

15        The work up of the amidines derived from hydroxy or carboxy substituted anilines required filtration of the aqueous washings to isolate additional quantities of undissolved product. Recrystallization of these products was carried out from ethanol. The time of the reaction and the properties of the product are given in Table 2.

TABLE 1

EX.	NAME	REACTION TIME	M.P. ° C	PHYSICAL PROPERTIES
5	N-benzyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine	4 hrs	129-133	tan colored solid
6	N-(Pyrid-4-yl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine	24 hrs	205-207	pale yellow solid
7	N-(Picol-4-yl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine	24 hrs	74-78	orange solid
8	N-(4-methoxybenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine	4 hrs	138-139	colorless crystalline solid
9	N-(4-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine	4 hrs	176-179	colorless crystalline solid
10	N-(2-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine	24 hrs	171-173	yellow solid

**EXAMPLE 11****N-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzimidino chloride**

To N-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamide (4.5 grams, 11.8 mmol) was added thionyl chloride (50 milliliters) and the resultant solution heated to reflux for 2.5 hours. Volatiles were removed *in vacuo*, and the resulting yellow residue azeotroped with toluene (3 x 50 milliliters) to afford a yellow solid. This solid was used for the synthesis of Examples 12 - 42 without further purification. Purification by flash chromatography (SiO<sub>2</sub>; ethyl acetate : pentane [2 : 3]) followed by recrystallization from ethyl acetate / pentane afforded an analytically pure sample of N-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzimidino

purified by chromatography on SiO<sub>2</sub> eluting with methylene chloride/ethanol/ammonia (9:1:0.1) to yield the title compound as a white solid (70 milligrams).

<sup>1</sup>H NMR (CDCl<sub>3</sub>; 250MHz) δ 9.28 (brs, 1H), 8.87 (brs, 1H), 7.16 (s, 1H), 6.84 (m, 3H), 5.69 (s, 1H), 5.46 (s, 1H), 4.75 (m, 1H), 3.83 (s, 3H), 1.81 (m, 6H), 1.57 (m, 2H).

#### EXAMPLES 5 - 10

##### N-Benzyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidines

A solution of N-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamide (1 gram, 2.62 mmol) in phosphoryl chloride (15 milliliters, 161 mmol) and N,N-dimethylaniline (0.75 milliliters) was heated at reflux under nitrogen for 20 hours. The reaction mixture was cooled to room temperature, volatiles removed *in vacuo*, and the brown residue azeotroped with toluene (3 x 20 milliliters). The crude imino chloride was dissolved in toluene (15 milliliters). In each case, an excess of the benzylamine (9 - 12 equivalents) was added in one portion and the mixture heated to reflux for a sufficient time under nitrogen. The reaction mixture was cooled to room temperature, volatiles removed *in vacuo*, and the residue dissolved in chloroform (100 milliliters) and washed with water (2 x 50 milliliters). The combined organics were dried (Na<sub>2</sub>SO<sub>4</sub>) and volatiles removed *in vacuo* to afford a colorless solid. The mixture was purified by flash chromatography (SiO<sub>2</sub>; ethyl acetate : hexane [1 : 9], followed by ethyl acetate : hexane [1 : 4]) to yield the desired product. The time of the reaction and the properties of the product are given in Table 1.

**EXAMPLE 4****Preparation of 1-(3-cyclopentyloxy-4-methoxyphenyl)-  
(2-(5-(pyrimid-2,4-dionyl)))ethanone**

- 5 a) [[1-(3-Cyclopentyloxy-4-methoxyphenyl)-1-ethenyl]  
oxy]trimethylsilane

10 Lithium diisopropylamide (1.5M solution in  
cyclohexane, 12.5 milliliters, 18.75 mmol) was added over  
3 minutes to a stirred solution of 3-cyclopentyloxy-4-  
methoxyacetophenone (3 grams, 12.8 mmol) in dry  
tetrahydrofuran (10 milliliters) at -78°C. After the  
15 addition was complete, the solution was stirred for 30  
minutes at -78°C and trimethylsilyl chloride (2.4  
milliliters, 30.72 mmol) was added in one portion. The  
mixture was allowed to warm to room temperature, stirred  
for 20 minutes, and quenched with saturated NaHCO<sub>3</sub> (35  
20 milliliters). The resulting mixture was extracted with  
hexane (2 x 50 milliliters), the organic layer dried  
(Na<sub>2</sub>SO<sub>4</sub>) and the solvent removed *in vacuo* to afford the  
title compound as a colorless oil (4 grams); 80% pure by  
gas chromatography/mass spectrometry.

- 25 b) 1-(3-cyclopentyloxy-4-methoxyphenyl)-(2-(5-(pyrimid-  
2,4-dionyl)))ethanone

30 A stirred solution of ([1-(3-cyclopentyloxy-4-  
methoxyphenyl)-1-ethenyl]oxy)trimethylsilane (4.0 grams,  
80% pure by gas chromatography, 10.3 mmol), 5-bromouracil  
(1.73 grams, 9.14 mmol), tributyltin fluoride (2.8 grams,  
9.14 mmol) and bis(triphenylphosphine)palladium (II)  
chloride (215 milligrams, 3.0 x 10<sup>-4</sup> mmol) in 1,4 dioxane  
(50 milliliters) was refluxed for 60 hours. The reaction  
mixture was cooled to room temperature, diluted with  
diethyl ether (150 milliliters) and washed with 1N NaOH  
35 (3 x 60 milliliters). The aqueous layer was neutralized  
with 12N HCl and extracted with methylene chloride (3 x  
50 milliliters). The organics were dried (Na<sub>2</sub>SO<sub>4</sub>) and the  
solvent removed *in vacuo* to afford an oil. The oil was

added to the reaction mixture and stirring continued overnight. The pyridine was removed *in vacuo* and the residue partitioned between ethyl acetate (200 milliliters) and water (200 milliliters). The aqueous phase was extracted with ethyl acetate ( 2 x 125 milliliters), the organics dried over Na<sub>2</sub>SO<sub>4</sub> and concentrated *in vacuo* to give an orange oil. The oil was purified by flash chromatography (SiO<sub>2</sub>:hexane/ethyl acetate (4:1)) to afford the title compound as a tan solid (2.49 grams).

R<sub>f</sub> (SiO<sub>2</sub>:ethyl acetate/hexane (3:7)) 0.25.

d) 1-(3-Cyclopentyloxy-4-methoxy-phenyl)phenone-O-(aminocarbonyl)oxime

Anhydrous trifluoroacetic acid (2.45 milliliters, 3.64 grams, 31.92 mmol) was added dropwise over 10 minutes at room temperature to a slowly stirred suspension of sodium cyanate (4.15 grams, 63.84 mmol) in methylene chloride (30 milliliters). The suspension slowly thickened to a gelatinous mass which was periodically agitated by hand. After 30 minutes at room temperature, 1-(3-cyclopentyloxy-4-methoxyphenyl)phenone oxime (2.49 grams, 7.99 mmol) in methylene chloride (10 milliliters) was added in one portion and the reaction mixture stirred under nitrogen for 1 hour. The reaction mixture was poured into saturated NaHCO<sub>3</sub> (100 milliliters) and extracted with methylene chloride (2 x 200 milliliters). The organic phase was washed with water (100 milliliters), dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated *in vacuo* to give a pale yellow oil. The oil was purified by flash chromatography (SiO<sub>2</sub>:methylene chloride/ ethyl acetate (9:1)) to yield the title compound as a white solid (1.21 grams). m.p. 129-132°C.

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 250MHz) δ 7.43 (m, 5H), 6.94 (m, 3H), 4.69 (m, 1H), 3.86 (s, 3H), 1.78 (m, 6H), 1.60 (m, 2H).

were dried over  $\text{Na}_2\text{SO}_4$  and concentrated *in vacuo* to give a light yellow oil. The oil was purified by flash chromatography ( $\text{SiO}_2$ :hexane/ ethyl acetate (4:1)) to afford the title compound as a pale yellow oil (7.4 grams).

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 250MHz)  $\delta$  7.30 (m, 5H), 6.84 (m, 3H), 5.76 (s, 1H), 4.72 (m, 1H), 3.81 (s, 3H), 2.26 (s, 1H), 1.85 (m, 6H), 1.59 (m, 2H).

b) 1-(3-Cyclopentyloxy-4-methoxyphenyl)phenone

Pyridinium dichromate (13.22 grams, 35.19 mmol) was added in one portion to a stirred solution of  $\alpha$ -phenyl-3-cyclopentyloxy-4-methoxybenzyl alcohol (7.0 grams, 23.5 mmol) in dry methylene chloride (200 milliliters) at room temperature. The resulting heterogeneous solution was stirred at room temperature overnight. The reaction mixture was diluted with an equal volume of diethyl ether and stirred for 1 hour. The mixture was filtered through celite and the filter cake washed with diethyl ether (150 milliliters) and ethyl acetate (150 milliliters). The brown filtrate was concentrated *in vacuo* and purified by flash chromatography ( $\text{SiO}_2$ :hexane/ ethyl acetate (7:3) to yield the title compound as an orange solid (6.940 grams).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 250MHz)  $\delta$  7.75 (m, 2H), 7.46 (m, 5H), 5.76 (s, 1H), 4.72 (m, 1H), 3.81 (s, 3H), 2.26 (s, 1H), 1.85 (m, 6H), 1.59 (m, 2H).

c) 1-(3-Cyclopentyloxy-4-methoxyphenyl)phenone oxime

Hydroxylamine hydrochloride (1.179 grams, 25.7 mmol) was added in one portion to a magnetically stirred solution of 1-(3-cyclopentyloxy-4-methoxyphenyl)phenone (6.936 grams, 23.4 mmol) in dry pyridine (120 milliliters) at room temperature. The resulting suspension slowly became homogeneous and the solution was stirred at room temperature overnight. Further hydroxylamine hydrochloride (0.5 grams, 7.17 mmol) was

5 The combined reaction mixtures were diluted with 800  
milliliters of hexane and applied to a flash  
chromatography column prepared from 470 grams of flash  
chromatography silica gel. Fractions of 800 milliliters  
10 were collected. Fractions 1-6 (hexane) contained only  
diphenyl ether. Fraction 7 (1:1 hexane/methylene  
chloride) contained 1 gram of material. Fractions 8-11  
(methylene chloride) contained 34.5 grams of material  
with a higher  $R_f$  on TLC (2% methanol/methylene chloride,  
15 silica gel) than the title compound. Fractions 12-17  
(methylene chloride) gave 20 grams (34%) of the crude  
title compound. A sample of this material (1.0 grams)  
was recrystallized from 10 milliliters of ethanol to give  
the pure title compound, MP 119-120°.

### EXAMPLE 3

#### Preparation of 20 1-(3-Cyclopentyloxy-4-methoxyphenyl)phenone-O- (aminocarbonyl)oxime

##### a) $\alpha$ -Phenyl-3-cyclopentyloxy-4-methoxybenzyl alcohol

Phenyllithium (1.8M solution in cyclohexane/diethyl  
ether, 25.5 milliliters, 46 mmol) was added dropwise over  
25 15 minutes to a stirred solution of 3-cyclopentyloxy-4-  
methoxybenz-aldehyde (6 grams, 27 mmol) in dry  
tetrahydrofuran (20 milliliters) at -78°C. The resulting  
solution was stirred at -78°C for 30 minutes and quenched  
30 at -78°C by the rapid addition of aqueous saturated  $\text{NH}_4\text{Cl}$   
(70 milliliters). After warming to room temperature,  
water was added to dissolve the solids and volatiles were  
removed *in vacuo*. The residue was partitioned between  
water (250 milliliters) and ethyl acetate (250  
35 milliliters), the aqueous phase was extracted with ethyl  
acetate (3 x 250 milliliters) and the combined organic  
layers washed with water (200 milliliters). The organics

overnight, water was added and stirring was continued. The layers were separated and the methylene chloride layer was washed with 100 milliliter portions of water, dilute aqueous HCl, and water. Evaporation of the methylene chloride afforded the solid amide which was triturated with methanol (20 milliliters) and filtered to give 10.7 grams (71%) of N-(3-cyclopentyloxy-4-methoxyphenyl-acetyl)-2-hydroxy-5-chloroaniline, MP 151-152°.

f) N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-allyloxy-5-chloroaniline

In this step, allyl chloride (23.3 grams, 0.31 mol) was added to a stirred solution of N-(3-cyclopentyloxy-4-methoxyphenylacetyl)-2-hydroxy-5-chloroaniline (78 grams, 0.21 mol) in ethanol (600 milliliters) and 1 N NaOH in methanol (213 milliliters). The mixture was heated under reflux for 8 hours and then diluted with water and extracted twice with ethyl acetate. Evaporation of the ethyl acetate and crystallization of the residue from methanol gave 56.4 grams (65%) of the title compound, MP 75-76.5°.

EXAMPLE 2

Preparation of N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-hydroxy-3-allyl-5-chloroaniline

A solution of N-(3-cyclopentyloxy-4-methoxyphenylacetyl)-2-allyloxy-5-chloroaniline (33 grams, 0.079 mol) in 330 milliliters of diphenyl ether was heated at 180° for 6.5 hours. This reaction mixture was combined with a second reaction mixture containing N-(3-cyclopentyloxy-4-methoxyphenylacetyl)-2-allyloxy-5-chloroaniline and 250 milliliters of diphenyl ether which had been heated at 180° for 20 hours.



several times with water and evaporated to yield 3-cyclopentyloxy-4-methoxyphenylacetonitrile (109 grams, 95%) for the subsequent transformation.

5

d) 3-Cyclopentyloxy-4-methoxyphenylacetic acid

A solution of 3-cyclopentyloxy-4-methoxyphenylacetonitrile (109 grams, 0.43 mol) in 1330 milliliters of ethanol and NaOH (51 grams, 1.3 mol) was heated under reflux for 48 hours. Ethanol (500 milliliters) was distilled from the reaction mixture and the residue was diluted with water and stirred with Norit A (11 grams) for 2 minutes. The mixture was filtered through a pad of celite and acidified to pH 1 with concentrated HCl. Extraction of the mixture with diethyl ether yielded 120 grams of crude 3-cyclopentyloxy-4-methoxy-phenylacetic acid after evaporation of the ether at reduced pressure. The crude acid was dissolved in warm toluene (400 milliliters) and stirred for 1 hour with 10.5 grams of Norit A. The charcoal was filtered and the toluene solution was diluted with heptane (40 milliliters). Filtration of the cooled solution afforded 72 grams (67%) of pure 3-cyclopentyloxy-4-methoxyphenylacetic acid, MP 79-80°.

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e) N-(3-Cyclopentyloxy-4-methoxy-phenylacetyl)-2-hydroxy-5-chloroaniline

A solution of 3-cyclopentyloxy-4-methoxyphenylacetic acid (10 grams, 0.040 mol) in 20 milliliters of methylene chloride was added dropwise to a stirred slurry of 1,1'-carbonyldiimidazole (7.1 grams, 0.044 mol) in 40 milliliters of methylene chloride. After stirring for 2 hours, the resulting solution was added to a solution of 2-hydroxy-5-chloroaniline (6.0 grams, 0.042 mol) in methylene chloride (75 milliliters). After stirring

30

35

**EXAMPLE 1****Preparation of N-(3-Cyclopentyloxy-4-methoxyphenyl-acetyl)-2-allyloxy-5-chloroaniline**5      a)      **3-Cyclopentyloxy-4-methoxybenzyl alcohol**

A solution of 3-cyclopentyloxy-4-methoxybenzaldehyde (38 grams, 0.17 mol) in 40 milliliters of ethanol and sodium borohydride (1.63 grams, 0.043 mol) was stirred for 2 hours at room temperature until complete by TLC. The reaction was diluted with water and extracted with ethyl acetate. Evaporation of the ethyl acetate afforded 3-cyclopentyloxy-4-methoxybenzyl alcohol (37 grams, 98%) suitable for the next step.

15      b)      **3-Cyclopentyloxy-4-methoxybenzyl chloride**

A solution containing 3-cyclopentyloxy-4-methoxybenzyl alcohol (112 grams, 0.50 mol), prepared as described in step a), in 1 liter of methylene chloride was stirred at room temperature with concentrated HCl (110 milliliters, 1.2 mol) for 3 hours, at which time the reaction was done by TLC. The layers were separated and the methylene chloride solution was washed twice with water and evaporated under reduced pressure to give 3-cyclopentyloxy-4-methoxybenzyl chloride (119 grams, 100%).

25      c)      **3-Cyclopentyloxy-4-methoxyphenylacetonitrile**

A mixture of 3-cyclopentyloxy-4-methoxybenzyl chloride (119 grams, 0.49 mol), 120 milliliters of methylene chloride, KCN (70.7 grams, 1.09 mol), benzyltriethylammonium chloride (35 grams, 0.015 mol) and water (120 milliliters) was stirred vigorously at room temperature for 48 hours. The reaction mixture was diluted with methylene chloride and the layers were separated. The methylene chloride solution was extracted

5 When the compounds of the present invention are  
incorporated for parenteral administration by injection  
(e.g., continuous infusion or bolus injection), the  
formulation for parenteral administration may be in the  
10 form of suspensions, solutions, emulsions in oily or  
aqueous vehicles, and such formulations may further  
comprise pharmaceutically necessary additives such as  
stabilizing agents, suspending agents, dispersing agents,  
sustained release agents, and the like. The compounds of  
the invention may also be in the form of a powder for  
reconstitution as an injectable formulation.

15 The dose of the compounds of the present invention  
is dependent upon the affliction to be treated, the  
severity of the symptoms, the route of administration,  
the frequency of the dosage interval, the presence of any  
deleterious side-effects, and the particular compound  
utilized, among other things.

20 The PDE IV inhibitory compounds of the present  
invention may be examined for their PDE IV inhibitory  
effects via the techniques set forth in the following  
examples, wherein the ability of the compounds to inhibit  
PDE IV isolated from bovine tracheal smooth muscle is set  
forth. The ability of the compounds to effect PDE III and  
V was also examined.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

25 The following examples illustrate various aspects of  
the present invention, and are not to be construed to  
limit the claims in any manner whatsoever. All of the  
30 compounds were examined and satisfactory NMR spectra were  
obtained.

5 In addition, when the compounds of the present invention are incorporated into oral dosage forms, it is contemplated that such dosage forms may provide an immediate release of the compound in the gastrointestinal tract, or alternatively may provide a controlled and/or sustained release through the gastrointestinal tract. A wide variety of controlled and/or sustained release formulations are well known to those skilled in the art, and are contemplated for use in connection with the formulations of the present invention. The controlled and/or sustained release may be provided by, e.g., a coating on the oral dosage form or by incorporating the compound(s) of the invention into a controlled and/or sustained release matrix.

15 Specific examples of pharmaceutically acceptable carriers and excipients that may be used for formulate oral dosage forms, are described in the Handbook of Pharmaceutical Excipients, American Pharmaceutical Association (1986), incorporated by reference herein. Techniques and compositions for making solid oral dosage forms are described in Pharmaceutical Dosage Forms: Tablets (Lieberman, Lachman and Schwartz, editors) 2nd edition, published by Marcel Dekker, Inc., incorporated by reference herein. Techniques and compositions for making tablets (compressed and molded), capsules (hard and soft gelatin) and pills are also described in Remington's Pharmaceutical Sciences (Arthur Osol, editor), 1553-1593 (1980), incorporated herein by reference. Techniques and composition for making liquid oral dosage forms are described in Pharmaceutical Dosage Forms: Disperse Systems, (Lieberman, Rieger and Banker, editors) published by Marcel Dekker, Inc., incorporated herein by reference.

Alternatively, alkali and alkaline earth metal salts are prepared by reaction of the compounds of the invention with the appropriate base via a variety of known methods. For example, the sodium salt of the compounds of the invention can be prepared via reacting the compound with sodium hydride.

Various oral dosage forms can be used, including such solid forms as tablets, gelcaps, capsules, caplets, granules, lozenges and bulk powders and liquid forms such as emulsions, solution and suspensions. The compounds of the present invention can be administered alone or can be combined with various pharmaceutically acceptable carriers and excipients known to those skilled in the art, including but not limited to diluents, suspending agents, solubilizers, binders, disintegrants, preservatives, coloring agents, lubricants and the like.

When the compounds of the present invention are incorporated into oral tablets, such tablets can be compressed, tablet triturates, enteric-coated, sugar-coated, film-coated, multiply compressed or multiply layered. Liquid oral dosage forms include aqueous and nonaqueous solutions, emulsions, suspensions, and solutions and/or suspensions reconstituted from non-effervescent granules, containing suitable solvents, preservatives, emulsifying agents, suspending agents, diluents, sweeteners, coloring agents, and flavorings agents. When the compounds of the present invention are to be injected parenterally, they may be, e.g., in the form of an isotonic sterile solution. Alternatively, when the compounds of the present invention are to be inhaled, they may be formulated into a dry aerosol or may be formulated into an aqueous or partially aqueous solution.

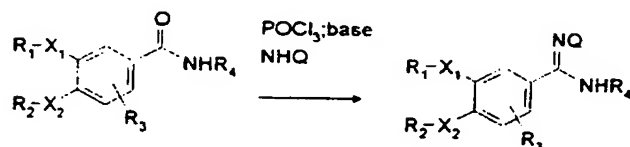
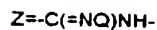
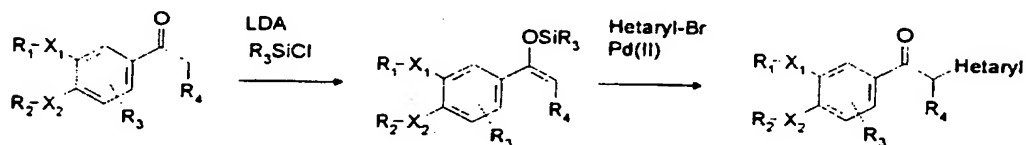
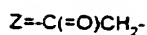
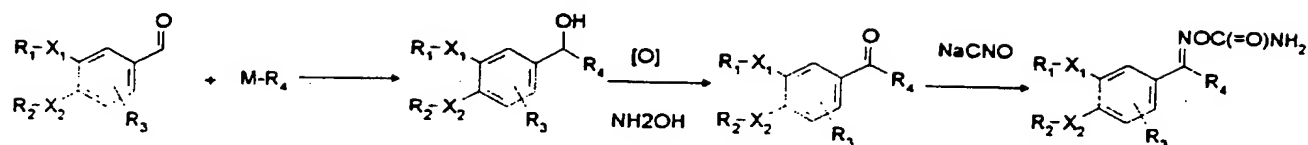
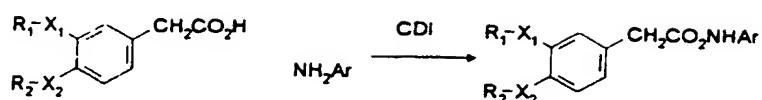
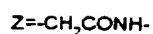
the  $IC_{50}$  for rolipram when run in the same assay was 2.8  $\mu M$ . It is apparent that this inventive compound is several times as effective as a PDE IV inhibitor as compared to rolipram (or theophylline).

5        Since the PDE III  $IC_{50}$  of Example 5 compound is  $>300 \mu M$ , it is clear that the compound of the invention is highly selective as a PDE IV inhibitor.

10        Furthermore, compounds of the present invention demonstrate significant PDE V inhibition properties. For example, the  $IC_{50}$  of the compound prepared in Example 5 was 2.8  $\mu M$ . Thus, this compound as well as others described herein can be used to effect PDE V inhibition in mammals to modulate cGMP content in vascular smooth muscle and utility in cardiovascular disorders such as  
15        hypertension, heart failure, peripheral vascular disease, stroke, atherosclerosis and angina as well as other disorders such as bronchitis, chronic asthma, allergic asthma, rhinitis, glaucoma and diseases characterized by disorders of gut motility such as irritable bowel  
20        syndrome (IBS). A combination of PDE IV and V inhibition may be beneficial in some therapeutic applications by virtue of affecting intracellular cyclic nucleotide levels by multiple pathways.

25        Accordingly, the compounds of the present invention can be administered to anyone requiring PDE IV and /or PDE V inhibition. Administration may be orally, topically, by suppository, inhalation or insufflation, or parenterally.

30        The present invention also encompasses all pharmaceutically acceptable salts of the foregoing compounds. One skilled in the art will recognize that acid addition salts of the presently claimed compounds may be prepared by reaction of the compounds with the appropriate acid via a variety of known methods.



Detailed description of several syntheses are shown in the Examples.

The compounds of the present invention have been found to be highly effective PDE IV inhibitors, the inhibition of which is in fact significantly and surprisingly greater than that of theophylline. The concentration which yields 50% inhibition of PDE IV ( $IC_{50}$ ) for the compound prepared in Example 5 is  $0.3 \mu M$ , whereas

(III) 1-(3-Cyclopentyloxy-4-methoxyphenyl)phenone-O-(aminocarbonyl)oxime;

(IV) 1-(3-cyclopentyloxy-4-methoxyphenyl)-(2-(5-(pyrimid-2,4-dionyl))) ethanone;

5 (V) N-Benzyl-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

(VI) N-(methylnaphth-1-yl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

10 (VII) N-(4-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

(VIII) N-(2-trifluoromethylbenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

15 (IX) N-(4-fluorophenyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine;

(X) N-(2-fluorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine, and

(XI) N-(2-chlorobenzyl)-N'-(3,5-dichloropyrid-4-yl)-3-cyclopentyloxy-4-methoxybenzamidine.

20 Representative processes for preparing the compounds of the present invention are shown below:



carboxamido or substituted or unsubstituted amino groups,  
or one or more lower alkyl groups having from 1 to 3  
carbon atoms;

Q is R<sub>4</sub>, H or lower alkyl;

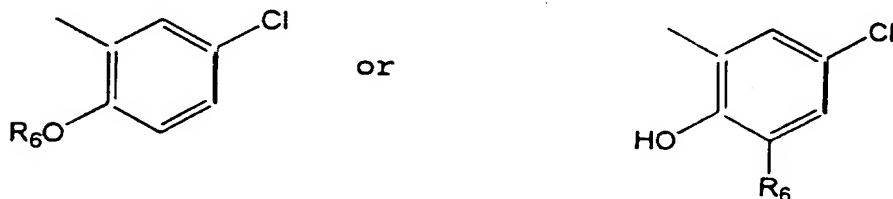
with the exceptions that:

when Z=-C(=NOCONHQ)-, R<sub>4</sub> is not benzyl;

when Q is H, Z is not -C(OQ)=N-; and

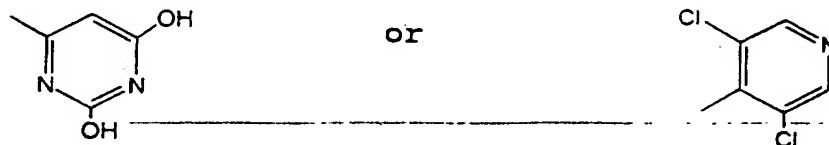
R<sub>1</sub> and R<sub>2</sub> are both not hydrogen.

In certain preferred embodiments, R<sub>4</sub> is a phenyl or  
substituted phenyl having one of the structures:



wherein R<sub>6</sub> is a substituted or unsubstituted lower alkyl  
having from about 1 to about 3 carbon atoms.

In another preferred embodiment R<sub>4</sub> is one of the  
following heteroaryl groups having the structure:

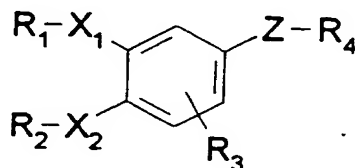


In further preferred embodiments, Z is a linkage  
NHCO-, -COCH<sub>2</sub>-, -CH<sub>2</sub>CO-, -C(=NQ)NH- and -C(=NOCONHQ)-.

Certain preferred compounds of the present  
invention include:

(I) N-(3-Cyclopentyloxy-4-methoxyphenyl-  
acetyl)-2-allyloxy-5-chloroaniline;

(II) N-(3-Cyclopentyloxy-4-methoxyphenyl-  
acetyl)-2-hydroxy-3-allyl-5-chloroaniline;



5

wherein

$X_1$  and  $X_2$  may be the same or different and each is O or S;

10

$R_1$  and  $R_2$  may be the same or different and each is selected from the group consisting of hydrogen, saturated or unsaturated straight-chain or branched  $C_{1-12}$  alkyl groups, cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 10 carbon atoms in the cycloalkyl moiety;

15

$R_3$  is hydrogen, halogen, or a saturated or unsaturated straight-chain or branched  $C_{1-12}$  alkyl group, a cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 7 carbon atoms in the cycloalkyl moiety;

20

$Z$  is a linkage selected from  $-NHCH_2-$ ,  $-CH_2NH-$ ,  $-CH_2CONH-$ ,  $-CH_2NHCO-$ ,  $-CH_2CO-$ ,  $-COCH_2-$ ,  $-CH_2COCH_2-$ ,  $-C(=NQ)NH-$ ,  $-C(=NOCONHQ)-$ ,  $-C(Cl)=N-$ ,  $-C(OQ)=N-$ ,  $-C(=NQ)NHNH$  and  $-C(NHNHQ)=N-$ ;

25

$R_4$  is a phenyl or benzyl or a 6-membered heteroaryl group which may be unsubstituted or substituted with one or more halogen atoms, alkyl groups, hydroxyl groups, cyano groups, nitro groups, carboxyl groups, alkoxy groups, alkoxycarbonyl, amido, carboxamido, substituted or unsubstituted amino groups, cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 10 carbon atoms in the cycloalkyl moiety, aryl or aralkyl groups preferably containing from about 6 to about 10 carbon atoms, or heterocyclic groups containing nitrogen, oxygen or sulfur in the ring; said alkyl, cycloalkyl, cycloalkyl-alkyl, aryl, and aryl-alkyl groups being unsubstituted or substituted by halogen atoms, hydroxyl groups, cyano groups, carboxyl groups, alkoxy groups, alkoxycarbonyl,

30

superior PDE IV inhibitory effect as compared to theophylline. In some aspects of the invention, the compounds also demonstrate significant PDE V inhibition.

5 The present invention is further related to a method for the treatment of allergic and inflammatory disease which comprises administering to a mammal in need thereof an effective amount of the compounds of the present invention.

10 The present invention is also related to a method for the mediation or inhibition of the enzymatic or catalytic activity of PDE IV activity in mammals, particularly humans, which comprises administering an effective amount of the above-described compounds of the invention to a mammal in need of PDE IV inhibition.

15 The compounds of the present invention may find use in the treatment of other disease states in humans and other mammals, such as in the treatment of disease states associated with a physiologically detrimental excess of tumor necrosis factor (TNF). TNF activates  
20 monocytes, macrophages and T-lymphocytes. This activation has been implicated in the progression of Human Immunodeficiency Virus (HIV) infection and other disease states related to the production of TNF and other cytokines modulated by TNF.

25 In certain preferred embodiments, the compounds of the present invention comprise the formula:

30

cyano groups, nitro groups, carboxyl groups, alkoxy groups, alkoxycarbonyl, amido, carboxamido, substituted or unsubstituted amino groups, cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 10 carbon atoms in the cycloalkyl moiety, aryl or aralkyl groups preferably containing from about 6 to about 10 carbon atoms, or heterocyclic groups containing nitrogen, oxygen or sulfur in the ring; said alkyl, cycloalkyl, cycloalkyl-alkyl, aryl, and aryl-alkyl groups being unsubstituted or substituted by halogen atoms, hydroxyl groups, cyano groups, carboxyl groups, alkoxy groups, alkoxycarbonyl, carboxamido or substituted or unsubstituted amino groups, or one or more lower alkyl groups having from 1 to 3 carbon atoms;

Q is R<sub>4</sub> or H or lower alkyl;  
with the exceptions that:  
when Z=-C(=NOCONHQ)-, R<sub>4</sub> is not benzyl;  
when Q is H, Z is not -C(OQ)=N-; and  
R<sub>1</sub> and R<sub>2</sub> are both not hydrogen.

The term "lower alkyl" is defined for purposes of the present invention as straight or branched chain radicals having from 1 to 3 carbon atoms.

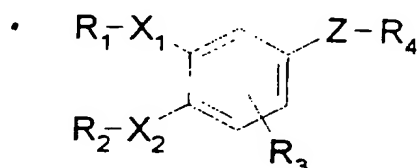
#### DETAILED DESCRIPTION

The compounds of the present invention, as demonstrated in the appended examples, are effective in the mediation or inhibition of PDE IV in humans and other mammals. Further, these compounds are selective PDE IV inhibitors which possess both bronchodilatory and anti-inflammatory properties substantially without undesirable cardiovascular stimulation caused by PDE III inhibition. Many of these compounds have a substantially equal or

disease state selected from the group consisting of asthma, arthritis, allergies, inflammation, depression, dementia and disease states associated with abnormally high physiological levels of cytokines.

It is another object of the present invention to provide new compounds which act as effective PDE V inhibitors.

With the above and other objects in view, the present invention mainly comprises a compound of the formula:



wherein:

$X_1$  and  $X_2$  may be the same or different and each is O or S;

$R_1$  and  $R_2$  may be the same or different and each is selected from the group consisting of hydrogen, saturated or unsaturated straight-chain or branched  $C_{1-12}$  alkyl groups, cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 10 carbon atoms in the cycloalkyl moiety;

$R_3$  is hydrogen, halogen, or a saturated or unsaturated straight-chain or branched  $C_{1-12}$  alkyl group, a cycloalkyl and cycloalkyl-alkyl groups containing from 3 to 7 carbon atoms in the cycloalkyl moiety;

Z is a linkage selected from  $-NHCH_2-$ ,  $-CH_2NH-$ ,  $-CH_2CONH-$ ,  $-CH_2NHCO-$ ,  $-CH_2CO-$ ,  $-COCH_2-$ ,  $-CH_2COCH_2-$ ,  $-C(=NQ)NH-$ ,  $-C(=NOCONHQ)-$ ,  $-C(Cl)=N-$ ,  $-C(OQ)=N-$ ,  $-C(NHNHQ)=N-$ , and  $-C(=NQ)NHNH$ ;

$R_4$  is a phenyl or benzyl or a 6-membered heteroaryl group which may be unsubstituted or substituted with one or more halogen atoms, alkyl groups, hydroxyl groups,

Attempts have therefore been made to find new compounds having more selective and improved PDE IV inhibition.

5

# OBJECTS AND SUMMARY OF THE INVENTION

It is accordingly a primary object of the present invention to provide new compounds which are effective PDE IV inhibitors.

10 It is another object of the present invention to provide new compounds which act as effective PDE IV inhibitors with lower PDE III inhibition.

15 It is a further object of the present invention to provide new compounds which have a superior PDE IV inhibitory effect as compared to theophylline or other known compounds.

20 It is a further object of the present invention to provide new compounds which have a substantially equal or superior PDE IV inhibitory effect as compared to known chemical compounds, and which exhibit surprisingly greater selectivity with regard to their inhibitory effects.

25 It is another object of the present invention to provide a method of treating a patient requiring PDE IV inhibition.

It is another object of the present invention to provide new compounds for treating disease states associated with abnormally high physiological levels of cytokines, including tumor necrosis factor.

30 It is another object of the present invention to provide a method of synthesizing the new compounds of this invention.

It is another object of the present invention to provide a method for treating a mammal suffering from a

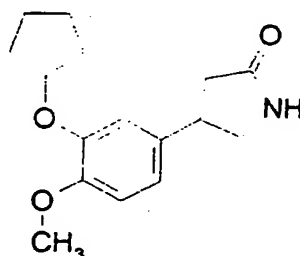
RO20-1724 and other PDE IV inhibitors have been shown to inhibit (1) mediator synthesis/release in mast cells, basophils, monocytes and eosinophils; (2) respiratory burst, chemotaxis and degranulation in neutrophils and eosinophils; and (3) mitogen-dependent growth and differentiation in lymphocytes (The PDE IV Family Of Calcium-Phosphodiesterases Enzymes, John A. Lowe, III, et al., Drugs of the Future 1992, 17(9):799-807).

PDE IV is present in all the major inflammatory cells in asthma including eosinophils, neutrophils, T-lymphocytes, macrophages and endothelial cells. Its inhibition causes down-regulation of cellular activation and relaxes smooth muscle cells in the trachea and bronchus. On the other hand, inhibition of PDE III, which is present in myocardium, causes an increase in both the force and rate of cardiac contractility. These are undesirable side effects for an anti-inflammatory agent. Theophylline, a non-selective PDE inhibitor, inhibits both PDE III and PDE IV, resulting in both desirable anti-asthmatic effects and undesirable cardiovascular stimulation. With this well-known distinction between PDE isozymes, the opportunity for concomitant anti-inflammation and bronchodilation without many of the side effects associated with theophylline therapy is apparent. The increased incidence of morbidity and mortality due to asthma in many Western countries over the last decade has focused the clinical emphasis on the inflammatory nature of this disease and the benefit of inhaled steroids. Development of an agent that possesses both bronchodilatory and anti-inflammatory properties would be most advantageous.

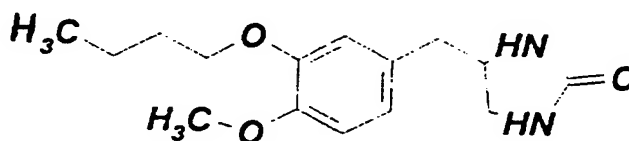
It appears that selective PDE IV inhibitors should be more effective with fewer side effects than theophylline.

depressant activity. PDE V appears to be important in regulating cGMP content in vascular smooth muscle, and therefore PDE V inhibitors may have cardiovascular activity.

5 While there are compounds derived from numerous structure activity relationship studies which provide PDE III inhibition, the number of structural classes of PDE IV inhibitors is relatively limited. Analogues of rolipram, which has the following structural formula:



and of RO-20-1724, which has the following structural formula:



25 have been studied.

30 Rolipram, which was initially studied because of its activity as an antidepressant has been shown to selectively inhibit the PDE IV enzyme and this compound has since become a standard agent in the classification of PDE enzyme subtypes. There appears to be considerable therapeutic potential for PDE IV inhibitors. Besides initial work suggesting an anti-depressive action, rolipram has been investigated for its anti-inflammatory effects, particularly in asthma. In-vitro, rolipram,



recently. Cyclic nucleotide phosphodiesterases (PDEs) have received considerable attention as molecular targets for anti-asthmatic agents. Cyclic 3',5'-adenosine monophosphate (cAMP) and cyclic 3',5'-guanosine monophosphate (cGMP) are known second messengers that mediate the functional responses of cells to a multitude of hormones, neurotransmitters and autocoids. At least two therapeutically important effects could result from phosphodiesterase inhibition, and the consequent rise in intracellular adenosine 3',5'-monophosphate (cAMP) or guanosine 3',5'-monophosphate (cGMP) in key cells in the pathophysiology of asthma. These are smooth muscle relaxation (resulting in bronchodilation) and anti-inflammatory activity.

It has become known that there are multiple, distinct PDE isoenzymes which differ in their cellular distribution. A variety of inhibitors possessing a marked degree of selectivity for one isoenzyme or the other have been synthesized.

The structure-activity relationships (SAR) of isozyme-selective inhibitors has been discussed in detail, e.g., in the article of Theodore J. Torphy, et al., "Novel Phosphodiesterase Inhibitors For The Therapy Of Asthma", Drug News & Perspectives, 6(4) May 1993, pages 203-214. The PDE enzymes can be grouped into five families according to their specificity toward hydrolysis of cAMP or cGMP, their sensitivity to regulation by calcium, calmodulin or cGMP, and their selective inhibition by various compounds. PDE I is stimulated by  $\text{Ca}^{2+}$ /calmodulin. PDE II is cGMP-stimulated, and is found in the heart and adrenals. PDE III is cGMP-inhibited, and inhibition of this enzyme creates positive inotropic activity. PDE IV is cAMP specific, and its inhibition causes airway relaxation, anti-inflammatory and anti-

COMPOUNDS FOR AND METHOD OF INHIBITING  
PHOSPHODIESTERASE IV

BACKGROUND OF THE INVENTION

5           Asthma is a complex disease involving the concerted  
actions of multiple inflammatory and immune cells,  
spasmogens, inflammatory mediators, cytokines and growth  
factors. In recent practice there have been four major  
10       classes of compounds used in the treatment of asthma,  
namely bronchodilators (e.g.,  $\beta$ -adrenoceptor agonists),  
anti-inflammatory agents (e.g., corticosteroids),  
prophylactic anti-allergic agents (e.g., cromolyn sodium)  
and xanthines (e.g., theophylline) which appear to  
15       possess both bronchodilating and anti-inflammatory  
activity.

          Theophylline has been a preferred drug of first  
choice in the treatment of asthma. Although it has been  
touted for its direct bronchodilatory action,  
20       theophylline's therapeutic value is now believed to also  
stem from anti-inflammatory activity. Its mechanism of  
action remains unclear. However, it is believed that  
several of its cellular activities are important in its  
activity as an anti-asthmatic, including cyclic  
25       nucleotide phosphodiesterase inhibition, adenosine  
receptor antagonism, stimulation of catecholamine  
release, and its ability to increase the number and  
activity of suppressor T-lymphocytes. While all of these  
actually may contribute to its activity, only PDE  
30       inhibition may account for both the anti-inflammatory and  
bronchodilatory components. However, theophylline is  
known to have a narrow therapeutic index, and a wide  
range of untoward side effects which are considered  
problematic.

          Of the activities mentioned above, theophylline's  
35       activity in inhibiting cyclic nucleotide  
phosphodiesterase has received considerable attention

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**(54) Title:** COMPOUNDS FOR AND METHOD OF INHIBITING PHOSPHODIESTERASE IV**(57) Abstract**

Novel compounds which are effective PDE IV inhibitors are disclosed. The compounds possess improved PDE IV inhibition as compared to theophylline or rolipram as well as with improved selectivity with regard to PDE III inhibition. In certain aspects of the invention, the compounds also demonstrate PDE V inhibition. Pharmaceutical compositions containing the same and methods of treatment are also disclosed.